

WINTER WHEAT RESPONSE TO NITROGEN, SULFUR, PHOSPHORUS, AND MICRONUTRIENTS

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INTRODUCTION

Winter wheat responds readily to fertilizer application throughout much of the Pacific Northwest dryland cereal production area. But fertilizer response and recommended rates of application are strongly affected by adequacy of moisture, crop rotation, landscape position, the rate of other elements applied, and past fertilizer practices (Leggett, 1959; Rasmussen and Rohde, 1991; Fiez et al., 1994).

Nitrogen (N) normally dominates fertilizer needs, and because of its almost universal response has received the most attention. It is perceived as the element where the rate is most accurately established, but this is an erroneous perception because of significant effects of drought stress on crop yield and N response (Rasmussen and Rohde, 1991). Available phosphorus (P) levels are normally adequate for dryland cereals, but responses are becoming more frequent as yields increase, tillage decreases, and portions of the landscape become eroded (Pan and Hopkins, 1991; Rasmussen and Douglas, 1992). The decision to apply P generally depends on type of tillage and expected yield (Rasmussen and Douglas, 1992). Sulfur (S) is frequently applied, often to ensure against deficiency because diagnostic criteria for its need are not highly accurate. Sulfur is generally applied in relation to the rate of N applied. The need for micronutrients in dryland cereals is not well established, and they are infrequently applied to ensure against deficiency.

We conducted this experiment to evaluate fertilizer response across the major climatic zones, evaluate the soil contribution to N needs, and investigate yearly effects on nutrient response. The 1992 crop-year had low spring rainfall and substantial drought, while the 1993 crop-year had abundant spring rainfall.

MATERIALS AND METHODS

A series of fertilizer experiments was set out in 1992 and 1993 in four climatic zones. Different sites were selected in each zone each year. Fertility treatments consisted of rates of N from 0 to 129 lbs/acre (0 to 111 at wheat/fallow sites in 1992), and included comparisons to measure P, S, and micronutrient response (Table 1).

Table 1. Fertilizer treatments applied to eight experiment sites. Umatilla county, Oregon 1992-1993.

Treatment Number	Nutrient Applied			
	N [†]	P	S	Micromix [‡]
	<i>lbs/acre</i>			
1	0	0	0	No
2	43	4	6	No
3	86	8	12	No
4	129	12	18	No
5	86	0	12	No
6	86	8	0	No
7	86	8	12	Yes

† N rates for wheat/fallow sites in 1992 were 0, 37, 74, and 111 lb/acre.

‡ Micromix (Zn, Mg, Mn, Fe, Cu, B, Mo, Co); spring foliar spray ; 2 qt/acre of Bushel Builder (McGregor Co.)

The experimental design consisted of a randomized block with three replications. Individual plots were 10 by 100 feet.

Experiments spanned average rainfall amounts and rotations ranging from 10-inch winter wheat/fallow to 19-inch winter wheat/spring pea (Table 2). One of eight sites (the 1993 19-inch wheat/fallow) contained elevated levels of residual N similar to that found in some annual cropping systems in the Palouse (Sowers et al., 1994).

Sites were located on gentle backslope landscape positions, with slope ranging from 1 to 9 percent. All sites had been routinely fertilized with N for many years. All sites had a history of S fertilization, but only the wheat/pea rotation sites had a history of P fertilization. Only the 1992 wheat/pea site had a Zn application within the previous four years. Sites generally had moderate levels of available P and S and low levels of available Zn in the upper 8 inches of soil, based on Oregon soil test guidelines (Marx et al., 1996).

Table 2. Climate, soil, and agronomic data for eight experiment sites. Umatilla county, Oregon 1992-1993.

Component	Year	Rainfall and Crop Rotation [†]			
		10WF	13WF	16WF	19WP
Soil series		Shano	Walla Walla		Athena
Soil organic matter (%)		0.9	1.1	2.1	2.7
Spring (April-May-June) rainfall (inches)	1992	2.8	2.6	2.4	3.2
	1993	3.3	6.3	7.8	10.3
Available N at seeding (lb/ac)	1992	66	90	-	80
	1993	62	78	84	156
Soil pH	1992	6.8	6.1	6.5	5.9
	1993	6.9	6.3	6.1	6.0
Soil test P (ppm)	1992	16	22	14	23
	1993	20	15	21	23
Soil test S (ppm)	1992	3.1	3.8	3.3	3.7
	1993	4.1	2.0	2.3	4.8
Soil test Zn (ppm)	1992	0.5	0.7	0.6	1.1
	1993	0.6	0.7	0.6	0.8

[†] Rainfall: average in inches/year; Crop rotation: WF = Wheat/Fallow, WP = Wheat/Pea.
Soil test pH, P, S, and Zn for 0-8 inch depth; Soil tests by Agricheck, Inc., Umatilla, OR.

Fertilizer was applied in mid-summer on fallow rotations and in early fall when following peas. Nitrogen was applied as a non-pressure solution of urea ammonium nitrate (32-0-0-0S), P as ammonium polyphosphate (11-37-0-0S), and S as ammonium thiosulfate (12-0-0-26S) shanked 5 inches deep on 10-inch spacing. Micronutrients were applied as a foliar application of Bushel Builder in the spring of the crop year.

Winter wheat was seeded by each farmer uniformly across the entire plot. Grain yield was determined by harvesting a 5 by 90 foot section with a plot combine. Winter and spring precipitation were measured at each site.

RESULTS AND DISCUSSION

Winter wheat responded to N fertilization very differently between 1992 and 1993 (Table 3). In 1992, a year with low spring rainfall, N response was minimal in all agronomic zones, and higher rates of application decreased yield in some instances. The reverse was generally true in 1993, a year with substantially greater than normal spring precipitation. Nitrogen increased wheat yield substantially in 1993, with the optimum rate not attained in some instances. This illustrates the dilemma of attempting to apply N to achieve high efficiency of use because N, to be effective, must be applied before spring rainfall is known. When spring rainfall is high, wheat is very responsive to N and a substantial yield penalty incurs when inadequate fertilizer is applied. The general tendency is to apply sufficient N to ensure adequacy for high yield situations. But in years with low spring rainfall, yield is restricted and considerable N either ends up as elevated

grain protein or remains in soil where it is subject to leaching and denitrification.

Winter wheat did not respond to P, S, or micronutrient application either year. Sodium bicarbonate extractable-P levels were between 14 and 23 ppm. These levels generally reflect the P status of the more fertile loess soils of the Columbia Plateau where P response in dryland cereals seldom occurs. None of the sites had a history of P application. None of the sites responded to S application, but this was not unexpected. All of the sites except the low rainfall one had a history of S application. Sulfur has substantial residual carryover, and S is applied more frequently than necessary in many instances because of the poor record of definitive plant and soil tests. None of the sites responded to micronutrient application, again suggesting adequate availability for dryland cereal production. Soil tests for zinc, the element most suspected of being deficient, tested low for available Zn (<1ppm) at all sites.

SUMMARY

The optimum N application rate in dryland regions of the Pacific Northwest depends to a large degree on yield level achieved which in turn is dependent on the amount of spring rainfall received. Predicting grain yield and N need before spring rainfall is known has considerably less accuracy than is desirable. But there are no easily-defined solutions to the problem since late-season N additions tend to increase grain protein more than yield. The lack of winter wheat response to P, S, and micronutrients indicates that these elements are either in adequate supply in soil or, in the case of S, are met by residual from past fertilizer practices where soils are not severely eroded.

Table 3. Winter wheat yield response to N, P, S, and micronutrients in 1992 and 1993. Umatilla county, Oregon.

N Rate [†]		Rainfall and Crop Rotation [‡]				
		10WF		13WF		16WF
<i>lbs/acre</i>		----- 1992 Grain Yield, <i>bushels/acre</i> -----				
0		27 <i>a</i>	66 <i>b</i>	57 <i>a</i>	43 <i>a</i>	
37		29 <i>a</i>	69 <i>b</i>	62 <i>ab</i>	49 <i>a</i>	
74		27 <i>a</i>	65 <i>b</i>	64 <i>b</i>	43 <i>a</i>	
111		29 <i>a</i>	60 <i>a</i>	64 <i>b</i>	45 <i>a</i>	
		----- 1993 Grain Yield, <i>bushels/acre</i> -----				
0		27 <i>a</i>	60 <i>a</i>	44 <i>a</i>	107 <i>a</i>	
43		41 <i>b</i>	76 <i>b</i>	63 <i>b</i>	116 <i>b</i>	
86		40 <i>b</i>	89 <i>c</i>	74 <i>c</i>	120 <i>c</i>	
129		42 <i>b</i>	96 <i>d</i>	86 <i>d</i>	117 <i>bc</i>	
Nutrient Added		Yield Response				
Phosphorus	1992	No	No	No	No	No
	1993	No			No	No
Sulfur	1992	No	No	No	No	No
	1993	No			No	No
Micronutrients	1992	No	No	No	No	No
	1993	No			No	No

† N rates for 19WP were 0, 43, 86, and 129 lb/acre

‡ Rainfall: average in inches/year; crop rotation: WF = Wheat/Fallow, WP = Wheat/Pea; numbers within each column with the same letter are not different at probability = 0.05.

REFERENCES

Fiez, T.E., B.C. Miller, and W.L. Pan. 1994. Winter wheat yield and grain protein across varied landscape positions. *Agron. J.* 86:1026-1032.

Leggett, G.E. 1959. Relationships between wheat yield, available moisture, and available nitrogen in eastern Washington

dryland areas. Washington Agric. Expt. Stn. Bull. 609.

Marx, E.S., J. Hart, and R.G. Stevens. 1996. Soil test interpretation guide. Oregon State Univ. Ext. Sv., Corvallis.

Pan, W.L., and A.G. Hopkins. 1991. Plant development and N and P use of winter barley: I. Evidence of water stress-induced P

deficiency in an eroded toposequence. *Plant Soil* 135:9-19.

Rasmussen, P.E., and C.L. Douglas Jr. 1992. The influence of tillage and cropping-intensity on cereal response to nitrogen, phosphorus, and sulfur. *Fert Res.* 31:15-19.

Rasmussen, P.E., and C.R. Rohde. 1991. Tillage, soil depth, and precipitation effects on wheat response to nitrogen. *Soil Sci. Soc. Am. J.* 55:121-124.

Sowers, K.E., W.L. Pan, B.C. Miller, and J.L. Smith. 1994. Nitrogen use efficiency of split nitrogen applications in soft white winter wheat. *Agron. J.* 86:942-948.